THERMAL EXPERT SYSTEM - TEXSYS

ADVANCED AUTOMATION OF A PROTOTYPIC THERMAL CONTROL SYSTEM FOR SPACE STATION

PRESENTED BY CHIN LIN

CREATED BY JEFF DOMINICK

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The Thermal Expert System (TEXSYS) was initiated in 1986 as a cooperative project between ARC and JSC as a way to leverage on-going work at both centers. JSC contributed Thermal Control System (TCS) hardware and control software, TCS operational expertise, and integration expertise. ARC contributed expert system and display expertise. The first years of the project were dedicated to parallel development of expert system tools, displays, interface software and TCS technology and procedures by a total of four organizations (two at ARC, two at JSC). A demonstration was planned as the final project milestone.

BACKGROUND

JSC DEVELOPING STATION THERMAL CONTROL SYSTEM

- New two-phase (liquid/vapor) technology
- Operational expertise

ARC CONDUCTING SYSTEMS AUTONOMY DEMONSTRATION PROGRAM

- Development of expert system and display tools
- Goal of real-time control and FDIR of a system

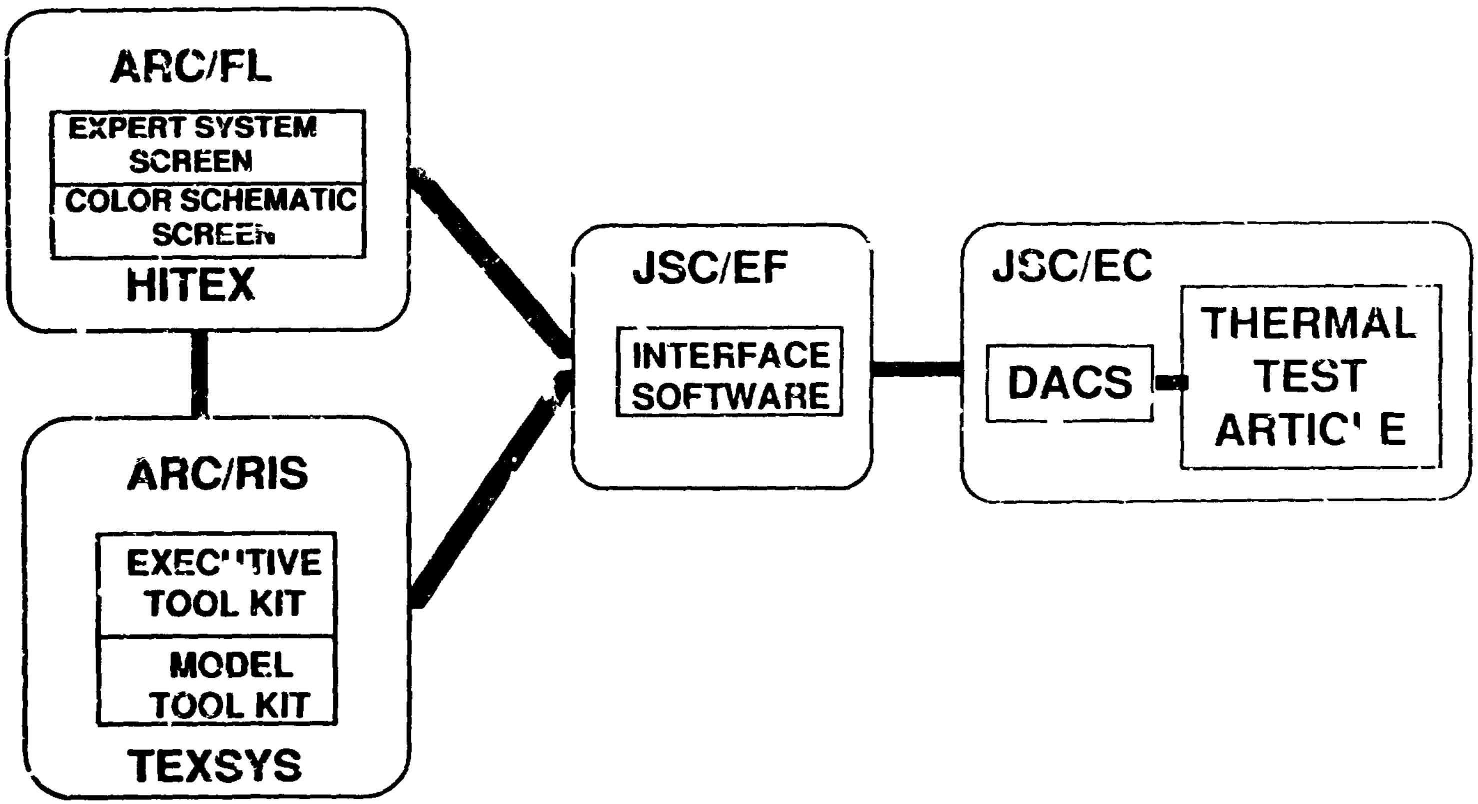
COOPERATIVE PROJECT

THERMAL EXPERT SYSTEM SELECTED 1986

- Parallel development of expert system tools, thermal technology, interface software
- Combined effort of two ARC (FL & RIS) and two JSC (EC & EF) organizations
- Demonstration planned as final milestone

TEXSYS consisted of four major software units layered on top of one another. JSC developed both the conventional control software that interacts with the test article and its interface software to the expert system. ARC developed the Thermal Expert System (TEXSYS) and the human interface to TEXSYS (HITEX). TEXSYS and HITEX each ran on a dedicated Symbolics computer, while the conventional control software ran on two microVax computers. All the computers were networked to one another, with the interface software distributed between all the computers.

OVERVIEW OF TEXSYS



TEXSYS is one of the first real time expert systems to perform control on a large, complex physical system. It was actually developed in an iterative fashion, with its first step to interact with a smaller TCS brassboard test article. The system was then upgraded to handle the actual test article and more faults, and was progressively tested and corrected to its final demonstration configuration. It uses model-based reasoning (327 rules and 3,493 frames) and its networking of software interfaces must fit into a 15 second cycle time.

SYSTEMS AUTONOMY DEMONSTRATION PROJECT

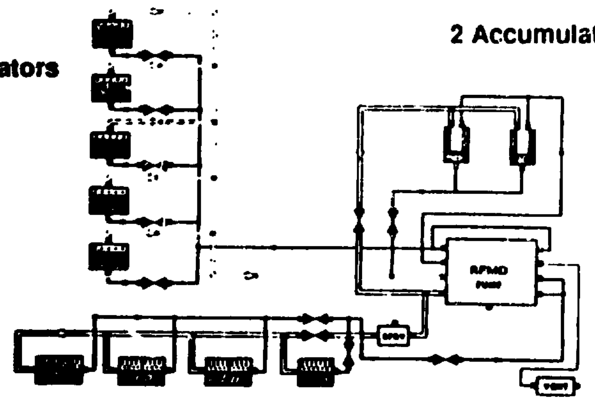
ADVANCED AUTOMATION DEMONSTRATION OF SPACE STATION FREEDOM THERMAL CONTROL SYSTEM

TECHNOLOGY CHALLENGE

EXPERT SYSTEM REALTIME CONTROL OF A COMPLEX ELECTRO-MECHANICAL SYSTEM

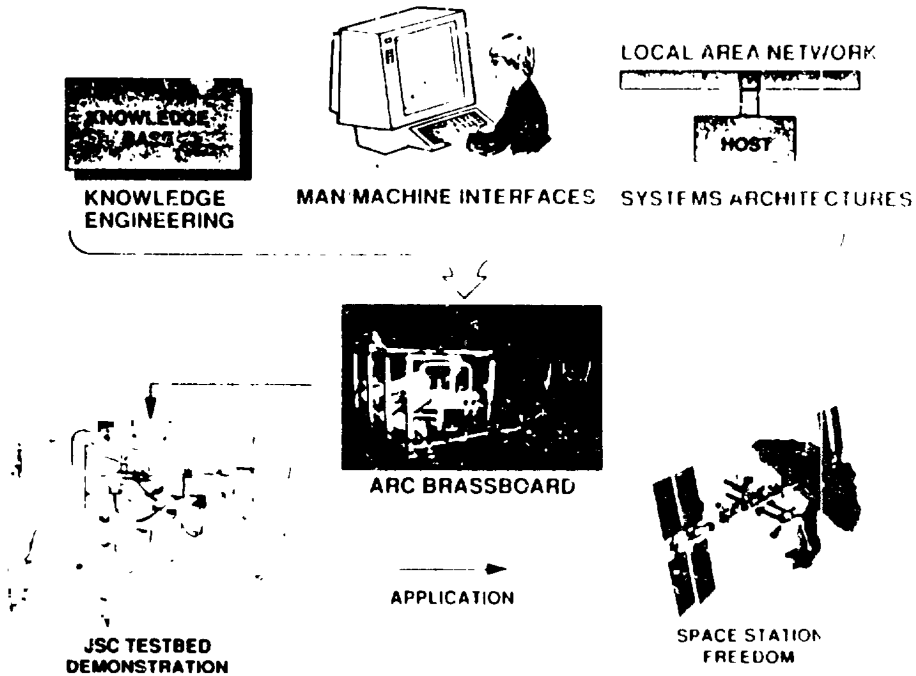
- ***Advanced Thermal Technology***
- ***Complex Physical System***

THERMAL CONTROL SYSTEM (TCS)
Two-Phase Anhydrous Ammonia System



TECHNOLOGY IMPLEMENTATION

JOINT ARC/JSC DEMONSTRATION



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TEXSYS was designed to conduct both real time control and fault detection, isolation and recovery (FDIR) of the thermal test article. From a list of 38 potential faults, ten faults were selected for implementation and demonstration in TEXSYS The test article was configured to allow detection of all 10 faults with varying levels of automatic recovery.

SPECIFIC FUNCTIONALITY TO BE DEMONSTRATED

REAL-TIME CONTROL

STARTUP

NORMAL OPERATIONS

SHUTDOWN

FAULT DETECTION, ISOLATION, AND RECOVERY OF 10 COMPONENT LEVEL FAULTS

1. Slow Leak
2. Pump Motor Failure
3. Single Evaporator Blockage
4. High Coolant Sink Temperature
5. Temp Valve Failure
6. NCG Buildup
7. Temp Valve Actuator Failure
8. Excessive Heat Load on Single Evaporator
9. Accumulator Position Sensor Failure
10. Pressure Sensor Failure

The TEXSYS project culminated with 5 months of integration and checkout, followed by a one week demonstration. TEXSYS successfully conducted all of its control and FDIR procedures. It proved to be generally reliable for conducting fault detection. Both the fault detection capability and the graphical displays were significant improvements over the conventional controller. Slowdowns in processing time decreased the reliability of the expert system. Future upgrades to the system should address the slowdowns and improve the fault detection explanation capability.

RESULTS

SOFTWARE INTEGRATION/CHECKOUT PERFORMED AT JSC MARCH - AUGUST 1989

- Simple interface tests approx 3 weeks
- Playback of pre-recorded test article data approx 3 months
- Actual interaction with live test article approx 6 weeks

DEMONSTRATION WEEK (8/28 - 9/1/89) SUCCESSFULLY SHOWED ALL NORMAL OPERATING PROCEDURES AND FAULT DETECTION ON ALL 10 FAULTS

STRENGTHS

- Significant improvement over previous capability
- Excellent graphical displays
- Generally reliable Fault Detection capability

WEAKNESSES

- Slowdowns in processing time decreased reliability, ease of use
- On-screen explainations need to be enhanced

Advanced automation technology provides useful tools to engineers attempting to capture and utilize design and operational expertise. TCS engineers can use this technology to better design thermal systems for future programs.

One of the biggest difficulties has been, and continues to be in the ability to design a system and in parallel design and codify its operational procedures. Advanced automation tools are beginning to add extra flexibility over conventional tools to better allow the capture of design and operational expertise as a system develops. Further research is required to find effective tools to checkout and certify this type of software.

The presentation concludes with self-descriptive two page list of Lessons Learned that were gained during the TEXSYS development and test.

CONCLUSIONS

1. TCS Engineers better prepared to develop automation software for Space Station, Advanced Programs.

2. Expert System community has more experience with large model-based expert systems for real-time process control.

3. Codifing new hardware operating procedures using new advanced automation techniques is a challenge.

4. Further research is needed into use of simulation software and other tools to develop and checkout expert systems.

LESSONS LEARNED

1. Identify user, focus on his application. Application and knowledge engineers should work together to:
   - Develop requirements early in the project
   - Define the operating and fault diagnosis procedures
   - Conduct a code walkthrough
   - Conduct hardware/software testing

2. New technology adds development time.
   - Application operational immaturity required extra time to develop fault diagnosis and recovery procedures
   - Real-time model-based expert system tools required development and checkout time

3. Iterative coding and testing is an effective expert system development process.
   - Brassboard testing stressed performance
   - Playback of pre-recorded test article data improved accuracy
   - Full-up testing is a final step

LESSONS LEARNED

4. Slow system, dedicated computers ease real-time performance problems.
   - TCS parameters, in general, change slowly with time (~seconds)
   - TEXSYS project employed two Symbolics computers (TEXSYS and HITEX) and two microVax computers (Conventional control and Interface software)
   - Network and microVaxes were tuned to optimize performance

5. Clean interfaces eased integration between conventional and expert system code.
   - ICD
   - Modular subroutines in conventional software

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